

**EXPRESS MAIL CERTIFICATE**

I HEREBY CERTIFY THAT THIS CORRESPONDENCE IS  
BEING DEPOSITED WITH THE UNITED STATES  
POSTAL SERVICE AS EXPRESS MAIL, POSTAGE  
PREPAID, IN AN ENVELOPE ADDRESSED TO:  
ASSISTANT COMMISSIONER FOR PATENTS,  
WASHINGTON, D.C. 20231 ON

April 4, 2001

SAID ENVELOPE HAVING AN EXPRESS MAIL MAILING  
LABEL NUMBER OF: EK565877855US

Margaret B. White

Margaret B. White

**POLYOLEFIN FOAM COMPOSITE STRUCTURE AND  
METHOD FOR MAKING THE SAME**

This Application is a Continuation-in-Part of U.S. Serial No.  
09/472,088, filed December 23, 1999.

**BACKGROUND OF THE INVENTION**

The present invention relates generally to polyolefin foams and,  
more particularly, to extruded polyethylene foam sheets having a coating  
disposed thereon for bonding the polyethylene foam sheet to a  
polypropylene foam sheet.

Polyolefin foams, particularly polyethylene foams, and methods for  
manufacturing such foams are well known in the art. See, e.g., U.S. Pat.  
Nos. 5,348,984 (Lee), 5,462,974 (Lee), and 5,667,728 (Lee), the  
disclosures of which are incorporated herein by reference thereto. One of  
the most common polyethylenes used is low density polyethylene (LDPE).

While polyethylene (PE) possesses a number of beneficial physical  
and chemical properties when used to produce a foamed sheet, a  
disadvantage of PE is that extruded foam sheets made therefrom have a  
flexural modulus that is lower than would otherwise be desired for

certain applications. For example, PE foams are commonly used to manufacture a type of flotation article known as a "bodyboard," which is a generally planar foamed structure of various shapes and sizes that allows individuals to be carried forward by oceanic waves as the waves break near the shore, i.e., to ride or "surf" the waves. This is commonly accomplished by grasping the edges of the bodyboard with a portion of the upper body positioned above, and often in contact with, the upper surface of the board. Individuals engaging in such activity generally prefer that the bodyboard be as stiff as possible as this allows the individual to maneuver the board to control somewhat the individual's direction of travel relative to the wave surface upon which the individual is "surfing." Too much flexure in the waveboard detracts from this ability to maneuver the board along the wave surface. Accordingly, efforts have been made to increase the stiffness of the foam used to make bodyboards.

One possible solution would be to construct the bodyboard from polypropylene (PP) foam, which is much stiffer than PE foam. However, PP foam has generally been found to be overly stiff and brittle, resulting in a bodyboard that is too easily damaged (e.g., gouged) and difficult to firmly grasp and handle, particularly when wet. In addition, PP foam has a surface texture that is uncomfortable against the skin, especially when rubbed against the skin as generally occurs during bodyboarding.

Another possibility would be to form a composite structure that includes a PE foam sheet bonded to a PP foam sheet. The PE foam sheet would provide comfort, grippability, and durability, while the PP foam sheet would provide increased stiffness and performance. Unfortunately, PP and PE foams are not chemically compatible and will not readily adhere to one another. Delamination is therefore a significant problem for PE foam/PP foam laminates.

It may be possible, in certain cases, to use special chemical adhesives (i.e., glues) to bond PP and PE foams. However, such adhesives are expensive. In addition, the process of coating and bonding is tedious and costly. The process involves slow production steps and the adhesives contain volatile organic solvents that are undesirable for release into the air. Extra equipment, therefore, is generally needed to recover the solvents, thus further adding to the expense and complexity of the adhesive coating process.

Accordingly, a need exists in the art for an economical and practical means for bonding PP foam to PE foam with sufficient strength that the resultant composite structure is suitable for commercial use, such as for bodyboards or other watersport applications.

#### SUMMARY OF THE INVENTION

That need is met by the present invention, which provides a composite structure, comprising:

- a. a foam sheet comprising polyolefin; and
- b. a coating disposed on at least one surface of the polyolefin foam sheet, the coating comprising at least one member selected from ethylene/propylene rubber, homogeneous ethylene/alpha-olefin copolymer, ethylene/acrylic acid copolymer, ethylene/vinyl acetate copolymer, and blends of the foregoing.

Advantageously, the coating is capable of bonding the polyolefin foam sheet to a second foam sheet having a different chemical composition than the polyolefin foam sheet at a bond strength of at least about 4 lb<sub>f</sub>/inch.

In a preferred alternative embodiment of the invention, a multilayer composite structure comprises:

- a. a first foam layer comprising polyethylene homopolymer or copolymer;
- b. a second foam layer comprising polypropylene homopolymer or copolymer; and
- 5 c. a coating disposed between and bonding the first and second foam layers together at a bond strength of at least about 4 lb<sub>f</sub>/inch, the coating comprising at least one member selected from ethylene/propylene rubber, homogeneous ethylene/alpha-olefin copolymer, ethylene/acrylic acid copolymer, ethylene/vinyl acetate copolymer, and blends of the
- 10 foregoing.

In accordance with yet another embodiment of the invention, a method for making a composite structure is provided, comprising:

- a. providing a foam sheet comprising polyolefin; and
- b. coating at least one surface of the polyolefin foam sheet, the
- 15 coating comprising at least one member selected from ethylene/propylene rubber, homogeneous ethylene/alpha-olefin copolymer, ethylene/acrylic acid copolymer, ethylene/vinyl acetate copolymer, and blends of the foregoing,

whereby, the coating is capable of bonding the polyolefin foam sheet

20 to a second foam sheet having a different chemical composition than the polyolefin foam sheet at a bond strength of at least about 4 lb<sub>f</sub>/inch.

As is explained in further detail below, the invention provides a means for bonding PE foam to PP foam with a solventless coating process, i.e., via a coating that contains substantially no volatile organic solvent.

25 Further, the resultant bond strength between the PE and PP foam sheets of at least 4 lb<sub>f</sub>/inch is sufficiently high for commercial watersport applications.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevational, cross-sectional view of a composite structure in accordance with the present invention;

FIG. 2 is an elevational, cross-sectional view of an alternative composite structure in accordance with the present invention; and

FIG. 3 is a schematic view of a preferred process for making the composite structure shown in FIG. 1.

### DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 illustrates a composite structure 10 in accordance with the present invention, including a foam sheet 12 and a coating 14 in adherence with the foam sheet and disposed on surface 16 thereof.

The foam sheet 12 in accordance with the invention comprises a polyolefin, such as polyethylene homopolymer or copolymer or polypropylene homopolymer or copolymer. Examples of useful polyethylene homopolymers include low density polyethylene and high density polyethylene. Polyethylene copolymers may include, e.g., homogeneous ethylene/alpha-olefin copolymers (i.e., metallocene/single-site catalyzed copolymers of ethylene and, e.g., one or more C<sub>3</sub> to C<sub>10</sub> alpha-olefin comonomers) or heterogeneous (i.e., Ziegler-Natta catalyzed) ethylene/alpha-olefin copolymers. A preferred polyethylene is low density polyethylene (LDPE) having a melt flow index ranging from about 1 to about 40 and a density ranging from about 0.915 to about 0.930 g/cc.

Various polypropylenes are suitable in accordance with the practice of the present invention, including atactic, isotactic, syndiotactic, long-chain branched, and propylene/ethylene copolymers. Preferred polypropylenes have a melt flow index ranging from about 1 to 20 and a density ranging from about 0.87 to 0.915 g/cc. Further, a high melt strength/long-chain branched polypropylene is preferred. Such

polypropylenes exhibit higher extensional viscosity when compared to other polypropylenes, resulting in beneficial strain hardening when the cells are expanded during the foaming process.

The foam sheet may have any desired thickness to suit the intended application, preferably ranging, e.g., from about 1/16 inch to about 5 inches. The foam may have any desired density, ranging, e.g., from about 1 to about 30 pounds/ft<sup>3</sup>. The density preferably ranges from about 1.5 to about 10 pounds/ft<sup>3</sup> and, most preferably, from about 2 to about 8 pounds/ft<sup>3</sup>. The foam sheet preferably has at least about 70 % closed cells, more preferably about 80 % closed cells and, most preferably, at least about 90 % closed cells.

In a preferred embodiment, the polyolefin foam sheet 12 comprises polyethylene homopolymer or copolymer having a density ranging from about 0.4 to about 15 pounds/ft<sup>3</sup>, more preferably from about 1 to about 10 pounds/ft<sup>3</sup>, and most preferably from about 2 to about 8 pounds/ft<sup>3</sup>.

In an alternative preferred embodiment, the polyolefin foam sheet 12 comprises polypropylene homopolymer or copolymer having a density ranging from about 0.5 to about 30 pounds/ft<sup>3</sup>, more preferably from about 1 to about 10 pounds/ft<sup>3</sup>, and most preferably from about 1 to about 6 pounds/ft<sup>3</sup>.

Any conventional chemical or physical blowing agents may be used. Preferably, the blowing agent is a physical blowing agent such as carbon dioxide, ethane, propane, n-butane, isobutane, pentane, hexane, butadiene, acetone, methylene chloride, any of the chlorofluorocarbons, hydrochlorofluorocarbons, or hydrofluorocarbons, as well as mixtures of the foregoing.

The blowing agent may be mixed with the polyolefin in any desired amount to achieve a desired degree of expansion in the resultant foam. Generally, the blowing agent may be added to the polyolefin in an amount

ranging from about 0.5 to 80 parts by weight, based on 100 parts by weight of the polyolefin. More preferably, the blowing agent is present at an amount ranging from 1 to 30 and, most preferably, from 3 to 15 parts per 100 parts by weight of the polyolefin.

5           If desired or necessary, various additives may also be included with the polyolefin. For example, it may be desirable to include a nucleating agent (e.g., zinc oxide, zirconium oxide, silica, talc, etc.) and/or an aging modifier (e.g., a fatty acid ester, a fatty acid amide, a hydroxyl amide, etc.). Other additives that may be included if desired are pigments, colorants,  
10       fillers, antioxidants, flame retardants, stabilizers, fragrances, odor masking agents, and the like.

          Foam in accordance with the present invention is preferably made by an extrusion process that is well known in the art. In such a process, the polyolefin is added to an extruder, preferably in the form of resin  
15       pellets. Any conventional type of extruder may be used, e.g., single screw, double screw, and/or tandem extruders. In the extruder, the resin pellets are melted and mixed. A blowing agent is preferably added to the melted polyolefin via one or more injection ports in the extruder. Any additives that are used may be added to the melted polyolefin in the extruder  
20       and/or may be added with the resin pellets. The extruder pushes the entire melt mixture (melted polyolefin, blowing agent, and any additives) through a die at the end of the extruder and into a region of reduced temperature and pressure (relative to the temperature and pressure within the extruder). Typically, the region of reduced temperature and pressure  
25       is the ambient atmosphere. The sudden reduction in pressure causes the blowing agent to nucleate and expand into a plurality of cells that solidify upon cooling of the polymer mass (due to the reduction in temperature), thereby trapping the blowing agent within the cells.

Referring again to FIG. 1, coating 14 preferably has a thickness ranging from about 0.5 to about 20 mils (1 mil = 0.001 inch); more preferably from about 1 to about 8 mils; and most preferably between about 1 and 6 mils. Coating 14 comprises at least one member selected from ethylene/propylene rubber, homogeneous ethylene/alpha-olefin copolymer, ethylene/acrylic acid copolymer, ethylene/vinyl acetate copolymer, and blends of the foregoing.

Suitable ethylene/propylene rubbers include both ethylene/propylene copolymer rubber and ethylene/propylene/diene terpolymer rubber. Ethylene/propylene copolymer rubber may have an ethylene content of from about 30 to about 80 wt. % (with the balance comprising propylene) while ethylene/propylene/diene terpolymer rubber may have an ethylene content of about 30 to about 70 wt. % and a diene content of from about 1 to about 10 wt. % (again, with the balance comprising propylene). More preferably, the ethylene content ranges from about 50 to about 75 wt. %. The typically used diene monomers are generally selected from the easily polymerizable non-conjugated dienes and can be straight chain, hydrocarbon diolefins or cycloalkenyl-substituted alkenes, having about 6 to about 15 carbon atoms. For example, 1,4-hexadiene may be used to make ethylene/propylene/1,4 hexadiene terpolymer. Other examples of useful diene monomers are dicyclopentadiene and 2-methylene-5-norbornene compounds. The degree of unsaturation is usually in the range of 2 to 15 double bonds per 1000 carbon atoms, distributed randomly on the polymer chain. Typically, ethylene-propylene rubbers are made from monomers that have a specific gravity in the neighborhood of 0.87.

If desired, e.g., for reasons of economy, the ethylene/propylene rubber may be blended with another material, such as a polyethylene

homopolymer or copolymer, a polypropylene homopolymer or copolymer, or blends thereof.

Coating 14 may also comprise homogeneous ethylene/alpha-olefin copolymer. As is well understood in the art, a "homogeneous" ethylene/alpha-olefin copolymer refers to ethylene/alpha-olefin copolymerization reaction products of relatively narrow molecular weight distribution and relatively narrow composition distribution. Homogeneous ethylene/alpha-olefin copolymers are structurally different from heterogeneous ethylene/alpha-olefin copolymers, in that homogeneous ethylene/alpha-olefins exhibit a relatively even sequencing of comonomers within a chain, a mirroring of sequence distribution in all chains, and a similarity of length of all chains, i.e., a narrower molecular weight distribution. Furthermore, homogeneous ethylene/alpha-olefin copolymers are typically prepared using metallocene, or other single-site type catalysts, rather than using Ziegler Natta catalysts. Such single-site catalysts typically have only one type of catalytic site, which is believed to be the basis for the homogeneity of the polymers resulting from the polymerization. A homogeneous ethylene/alpha-olefin copolymer can, in general, be prepared by the copolymerization of ethylene and any one or more alpha-olefin. Preferably, the alpha-olefin is a C<sub>3</sub>-C<sub>20</sub> alpha-monoolefin, more preferably, a C<sub>4</sub>-C<sub>12</sub> alpha-monoolefin, still more preferably, a C<sub>4</sub>-C<sub>8</sub> alpha-monoolefin. Still more preferably, the alpha-olefin comprises at least one member selected from the group consisting of 1-butene, 1-pentene, 1-hexene, and 1-octene.

Homogeneous, as opposed to heterogeneous, ethylene/alpha-olefin copolymers have been found to provide excellent adhesion between, e.g., a polyethylene foam sheet and a polypropylene foam sheet, and therefore are beneficially employed in a coating in accordance with the present invention. Preferred homogeneous ethylene/alpha-olefins have a density

of less than about 0.94 g/cc, more preferably less than 0.92 g/cc, and most preferably less than about 0.91 g/cc.

Ethylene/acrylic acid copolymer (EAA) has also been found to provide good adhesion between PE and PP foam sheets. Such materials are generally less preferred, however, due to their relatively high cost in comparison with EPR and homogeneous ethylene/alpha-olefin copolymer.

A highly preferred material for coating 14 is ethylene/vinyl acetate copolymer (EVA). Such material has been shown to provide excellent bonding with both PE and PP foam. Preferred EVAs have a vinyl acetate content of up to 33% by weight and a melt index of at least 3 g/10 min. If desired, the EVA may be blended with polyethylene homopolymer or with homogeneous or heterogeneous ethylene/alpha-olefin copolymer.

Advantageously, coating 14 may be substantially solventless, i.e., containing substantially no volatile organic carrier fluids to either evaporate into the environment or be recovered by expensive pollution-control equipment. This is because the coating in accordance with the invention is not a solvent-based adhesive but is, in a preferred embodiment, a thermoplastic polymer composition that can be melted and coated onto a surface of the foam sheet by, e.g., extrusion-coating or coextruding the coating onto the foam as described in more detail below. Instead of relying on evaporation of a solvent in order for the coating to cure, a thermoplastic coating in accordance with the present invention simply cools and solidifies, with little or no evaporation of volatile organic solvents.

At the same time, coating 14 has been found capable of bonding foam sheet 12 to a second foam sheet having a different chemical composition, i.e., different from that of foam sheet 12, at a bond strength of at least about 4 lb<sub>f</sub>/inch. This has been determined to be the minimum acceptable bond strength for commercial applications, e.g., for bodyboard

or other watersport use. As demonstrated in the examples, EPR, homogeneous ethylene/alpha-olefin copolymer, EAA, and EVA have been shown to be capable of bonding PE foam to PP foam at a bond strength greater than 4 lb<sub>f</sub>/inch. A more preferred bond strength is at least about 4.5 lb<sub>f</sub>/inch.

When a second foam sheet, comprising a material of a different chemical composition than polyolefin foam sheet 12, is bonded via coating 14 to foam sheet 12, a number of combinations of different foam/foam laminates are possible. In one such combination, polyolefin foam sheet 12 having coating 14 thereon may comprise polyethylene homopolymer or copolymer while a second foam sheet bonded to surface 18 of coating 14 comprises polypropylene homopolymer or copolymer. The inverse is also possible, i.e., where the coated polyolefin foam sheet 12 comprises polypropylene homopolymer or copolymer and the second foam sheet bonded to surface 18 of coating 14 comprises polyethylene homopolymer or copolymer.

A preferred multilayer composite structure 20 for use as a bodyboard is illustrated in FIG. 2. The composite structure includes a first foam layer 22 comprising polyethylene homopolymer or copolymer, a second foam layer 24 comprising polypropylene homopolymer or copolymer, and a coating 26 disposed between and bonding the first and second foam layers together at a bond strength of at least about 4 lb<sub>f</sub>/inch. The composition of coating 26 is as described above with respect to coating 14. For bodyboard applications, first foam layer 22 preferably comprises low density polyethylene having a density ranging from about 0.4 to about 15 pounds/ft<sup>3</sup> and a thickness ranging from about 1/16 to about 1 inch, while second foam layer 24 preferably comprises polypropylene homopolymer having a density ranging from about 0.5 to about 10 pounds/ft<sup>3</sup> and a thickness ranging from about 1 to about 4 inches.

Coating 26 is preferably as thin as possible, ranging from about 1 to about 5 mils.

The composite structure 20 is highly advantageous when used to form a bodyboard, with the PE foam sheet 22 providing comfort, grippability, and durability and the PP foam sheet 24 providing stiffness for good maneuverability while surfing. In addition, the coating 26 in accordance with the present invention provides a strong bond between the PE and PP foam sheets. If desired, an additional PE foam sheet, similar or identical to first foam layer 22, can be bonded to surface 28 of PP foam sheet 24 via a second coating layer 26 disposed between the additional PE foam sheet and surface 28 of PP foam sheet 24. In this configuration, relatively thin PE foam sheets form "skin" layers around a relatively thick "core" PP foam layer. This is a particularly advantageous configuration for bodyboard use as the outermost principle surfaces of the composite have the comfort and grippability of PE foam with a rigid PP foam core for enhanced wave riding performance.

Having now described composite structures in accordance with the invention, a preferred method for making composite structure 10 (FIG. 1) will be discussed with reference to FIG. 3. Foam sheet 12 is unwound from a storage roll 30 and sent to nip roller 32. Simultaneously, coating 14 is extruded onto surface 16 of foam sheet 12 between nip roller 32 and chill roller 34. This is a result of placing resin pellets of the polymer(s) used to make coating 14 into hopper 36, from which they enter extruder 38 wherein the pellets are mixed and melted. The resulting molten polymer is extruded into and through die 40 and onto surface 16 of foam sheet 12 as shown. Chill roller 34 is maintained at a sufficiently low temperature, e.g., less than about 65 °F, to cause the extruded polymer blend to solidify into coating 14 in adherence with foam sheet 12. In addition, nip roller 32 and chill roller 34 are urged against one another,

e.g., by mechanical or pneumatic means, with sufficient pressure to facilitate the bonding of the coating to the foam by squeezing the film and foam together as they pass between the two rollers. A third roller 42 may also be included to keep the resultant composite structure 10 in contact  
 5 with chill roller 34 for a full half revolution about the chill roller, and to again apply pressure to the film/foam composite to facilitate bonding of the two materials. The finished composite structure 10 is then wound on storage roll 44.

The foregoing process is known as an extrusion coating process  
 10 because the film is extruded in a molten state onto a previously formed and solidified foam sheet, whereon the film congeals and solidifies. Such a process is well known and further described, e.g., in U.S. Pat. No. 3,616,020. It is to be understood, however, that a method in accordance with the present invention is not limited to the illustrated extrusion  
 15 coating process. Many alternatives are possible. For instance, instead of the 'off-line' extrusion coating process illustrated in FIG. 3, wherein a previously made foam sheet is taken from a storage roll, an 'in-line' process may be employed wherein the foam sheet can be extruded from a die and allowed to travel a sufficient distance to solidify before being  
 20 coated, without the intermediate steps of winding and unwinding the foam on and from a storage roll. As a further alternative, a coextrusion process may be used in which the coating and foam are simultaneously extruded from separate dies and brought into contact with one another while both are still in a molten state.

25 In order to make the composite structure 20 as shown in FIG. 2, either the PE foam sheet 22 or PP foam sheet 24 may be coated with coating 26, e.g., by extrusion coating as shown in FIG. 3. Thereafter, the other foam sheet is laminated to the coated surface, i.e., to coating 26, preferably by applying heat to one or both surfaces to be bonded, and then

pressing the coated foam and non-coated foam together, e.g., between a pair of nip rollers. Alternatively, the entire three-layer structure can be coextruded.

5           These and other aspects and advantages of the invention may be further understood by reference to the following examples, which are provided for illustrative purposes only and are not intended in any way to be limiting.

10

### EXAMPLES

LDPE foam sheet having a density of 8 pounds/ft<sup>3</sup> (pcf) and a thickness of 3/16 inch was made using a standard extrusion process as described above. The sheet was wound in the form of a roll. The roll was mounted on an extrusion coating apparatus for applying a coating in accordance with the present invention on one surface of the foam sheet.

15

In the extrusion coating apparatus, resins used for the various coating formulations of Examples 1-8 were melted in a single screw extruder, sent through a cast die, and coated onto one surface of the LDPE foam sheet. The coated foam sheet then traveled between a pair of nip rollers. The resultant coatings for Examples 1-6 had a thickness of approximately 5 mils (0.005 inch) while the coatings for Examples 7-8 had a thickness of approximately 3.5 mils.

20

The resins used for each of the coatings in Examples 1-8 (the control sample had no coating) are summarized in Table 1.

25

**TABLE 1**

<b>Resin</b>	<b>D e s c r i p t i o n</b>
EPR	ADFLEX KS359P ethylene/propylene rubber having between 50 and 75 wt.% ethylene and dispersed in polypropylene; commercially available from Montell North America, Inc., Wilmington, Delaware.
LDPE	DOW LDPE 4012 low density polyethylene, commercially available from Dow Chemical, Midland, MI, having a density of 0.916 g/cc and a MI of 12.
MC-EAO1	ATTANE 4404 metallocene-catalyzed (homogeneous) ethylene/alpha-olefin (octene) copolymer having a density of 0.904 g/cc and a MI of 4.0; commercially available from Dow Chemical.
EAA	PRIMACORE 3440 ethylene/acrylic acid copolymer having a density of 0.938 g/cc and a MI of 10.5; commercially available from Dow Chemical.
MC-EAO2	AFFINITY PT1450 metallocene-catalyzed (homogeneous) ethylene/alpha-olefin (octene) copolymer having a density of 0.902 g/cc and a MI of 7.5; commercially available from Dow Chemical.
EVA	ESCORENE LD723.28 ethylene/vinyl acetate copolymer having a vinyl acetate content of 19.3 wt.%, a density of 0.94 g/cc, and a MI of 22.5; commercially available from ExxonMobil Chemical.

The following summarizes the extrusion-coating conditions for Examples 1-6:

5

Screw speed: 33-34 rpm

Total output rate: 88-91 Kg/hr

Melt temperature (measured at the die): 370-373 °F

Die pressure: 1200-2000 psi

Nip roll temperature: 65 °F

10

For Examples 7-8, the extrusion-coating conditions were as follows:

Screw speed: 18 rpm

Total output rate: 95.5 Kg/hr

Melt temperature (measured at the die): 347 °F

15

Die pressure: 500 psi

Nip roll temperature: 65 °F

Samples of the coated and uncoated ("control") foam sheets were bonded to the surface of a polypropylene plank having a thickness of about 2.25 inches and a density of either 1.5 pcf or 1.9 pcf (Example 7 only) using a hot air lamination process in which both surfaces to be bonded together were contacted with air maintained at 400 °F, and then the two foams were pressed together by squeezing them between a pair of nip rollers such that the two heated surfaces were urged together to form a bond. In the case of the coated samples (Examples 1-8), the coated surface of the LDPE foam sheet was heated and brought into contact with the heated surface of the PP foam.

The bond strengths between the LDPE and PP foams of the resultant composite structures were then tested using an INSTRON measurement device in accordance with ASTM F904-98 as follows:

1. Test samples of each foam sheet were prepared, each sample being 1 inch wide and 3 inches in length;

2. Initiated separation of the foam sheets at the foam/foam interface of each test sample at one end thereof;

3. Clamped each separated end of the test specimen in one of the two jaws of the INSTRON device using a starting jaw distance of 25.4 mm (1.0 inch); and

4. Activated the INSTRON device by causing the jaws to separate from one another at a speed of 4 inches/minute (this was slower than 10 inches/minute as specified in the ASTM procedure, due to the fact that the bond strength of a foam/foam laminate was tested, as opposed to a film/film laminate, for which a higher separation speed is more appropriate). The maximum force required to separate each test specimen was measured and recorded. This value is reported as the "Bond Strength" in Tables 2-4 (i.e., maximum separation force/inch width of the tested specimen).

**TABLE 2**

	<b>Control</b>	<b>Example 1</b>	<b>Example 2</b>	<b>Example 3</b>	<b>Example 4</b>	<b>Example 5</b>	<b>Example 6 (Compar.)</b>
Coating	None	Ethylene-Propylene Rubber (EPR)	EPR/LDPE blend at 70%/30% by weight	MC-EAO1	Ethylene/Acrylic Acid Copolymer (EAA)	MC-EAO2	MC-EAO2/LDPE blend at 70%/30% by weight
Bond Strength, lbf/inch	1.51	6.3	4.74	5.46	5.03	5.04	3.47
% Increase in Adhesion Strength*	--	317%	214%	262%	233%	233%	130%
Comments	PE foam peels easily from PP foam.	Excellent adhesion between PE and PP surfaces.	Excellent adhesion between PE and PP surfaces.	Excellent adhesion between PE and PP surfaces.	Excellent adhesion between PE and PP surfaces.	Excellent adhesion between PE and PP surfaces.	Moderate adhesion between PE and PP surfaces.

\* ((Force required for coated sample-Force required for uncoated sample)/(Force required for uncoated sample)) x 100

As indicated by the results in Table 2, all coatings in Examples 1-6 provided an increase in adhesion between the LDPE and PP foam sheets vs. the Control structure, which had no coating disposed between the foam sheets. The composite structures of Examples 1-5 demonstrated a sufficiently high bond strength for commercial use. In fact, the bond strength between the foam sheets of Examples 1-5 was so strong that, instead of delamination between the foam sheets, most of the separation occurred within the LDPE foam sheet as cohesive failure. The bond strength of the Example 6 composite structure was observed to be insufficient for commercial applications. The minimum bond strength for commercial applicability thus appears to be about 4 lbf/inch.

For Example 7, an EVA-coated LDPE foam sheet was laminated to a "beaded" PP foam plank having a density of 1.9 pcf. The beaded PP foam was made by using moldable polypropylene beads, which were impregnated with a blowing agent (n-butane) and then flash expanded to

make cellular beads. The cellular beads were then molded to give a shape of a plank. Bond-strength data is set forth in Table 3.

**TABLE 3**

	<b>Control</b>	<b>Example 7</b>
Coating	None	3.5 mil EVA
Bond Strength, lb <sub>f</sub> /inch	1.51	13.96
% increase in adhesion	--	825%*
Comments	PE foam peels easily from PP foam	Excellent adhesion between PE and PP foam surfaces.

\* (Force required for coated sample-Force required for uncoated sample)/(Force required for uncoated sample) x 100

Example 8 was similar to Example 7, except that the EVA-coated LDPE foam sheet was laminated to an extruded PP foam plank having a density of 1.5 pcf. Bond-strength data is set forth in Table 4.

**TABLE 4**

	<b>Control</b>	<b>Example 8</b>
Coating	None	3.5 mil EVA
Bond Strength, lb <sub>f</sub> /inch	1.51	15.83
% increase in adhesion	--	948.3%
Comments	PE foam peels easily from PP foam	Excellent adhesion between PE and PP foam surfaces.

\* (Force required for coated sample-Force required for uncoated sample)/(Force required for uncoated sample) x 100

As indicated by the results in Tables 3-4, EVA coatings provide an exceptional degree of adhesion between LDPE and PP foam sheets.

While the invention has been described with reference to illustrative examples, those skilled in the art will understand that various

modifications may be made to the invention as described without departing from the scope of the claims which follow.

11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65  
66  
67  
68  
69  
70  
71  
72  
73  
74  
75  
76  
77  
78  
79  
80  
81  
82  
83  
84  
85  
86  
87  
88  
89  
90  
91  
92  
93  
94  
95  
96  
97  
98  
99  
100  
101  
102  
103  
104  
105  
106  
107  
108  
109  
110  
111  
112  
113  
114  
115  
116  
117  
118  
119  
120  
121  
122  
123  
124  
125  
126  
127  
128  
129  
130  
131  
132  
133  
134  
135  
136  
137  
138  
139  
140  
141  
142  
143  
144  
145  
146  
147  
148  
149  
150  
151  
152  
153  
154  
155  
156  
157  
158  
159  
160  
161  
162  
163  
164  
165  
166  
167  
168  
169  
170  
171  
172  
173  
174  
175  
176  
177  
178  
179  
180  
181  
182  
183  
184  
185  
186  
187  
188  
189  
190  
191  
192  
193  
194  
195  
196  
197  
198  
199  
200  
201  
202  
203  
204  
205  
206  
207  
208  
209  
210  
211  
212  
213  
214  
215  
216  
217  
218  
219  
220  
221  
222  
223  
224  
225  
226  
227  
228  
229  
230  
231  
232  
233  
234  
235  
236  
237  
238  
239  
240  
241  
242  
243  
244  
245  
246  
247  
248  
249  
250  
251  
252  
253  
254  
255  
256  
257  
258  
259  
260  
261  
262  
263  
264  
265  
266  
267  
268  
269  
270  
271  
272  
273  
274  
275  
276  
277  
278  
279  
280  
281  
282  
283  
284  
285  
286  
287  
288  
289  
290  
291  
292  
293  
294  
295  
296  
297  
298  
299  
300  
301  
302  
303  
304  
305  
306  
307  
308  
309  
310  
311  
312  
313  
314  
315  
316  
317  
318  
319  
320  
321  
322  
323  
324  
325  
326  
327  
328  
329  
330  
331  
332  
333  
334  
335  
336  
337  
338  
339  
340  
341  
342  
343  
344  
345  
346  
347  
348  
349  
350  
351  
352  
353  
354  
355  
356  
357  
358  
359  
360  
361  
362  
363  
364  
365  
366  
367  
368  
369  
370  
371  
372  
373  
374  
375  
376  
377  
378  
379  
380  
381  
382  
383  
384  
385  
386  
387  
388  
389  
390  
391  
392  
393  
394  
395  
396  
397  
398  
399  
400  
401  
402  
403  
404  
405  
406  
407  
408  
409  
410  
411  
412  
413  
414  
415  
416  
417  
418  
419  
420  
421  
422  
423  
424  
425  
426  
427  
428  
429  
430  
431  
432  
433  
434  
435  
436  
437  
438  
439  
440  
441  
442  
443  
444  
445  
446  
447  
448  
449  
450  
451  
452  
453  
454  
455  
456  
457  
458  
459  
460  
461  
462  
463  
464  
465  
466  
467  
468  
469  
470  
471  
472  
473  
474  
475  
476  
477  
478  
479  
480  
481  
482  
483  
484  
485  
486  
487  
488  
489  
490  
491  
492  
493  
494  
495  
496  
497  
498  
499  
500  
501  
502  
503  
504  
505  
506  
507  
508  
509  
510  
511  
512  
513  
514  
515  
516  
517  
518  
519  
520  
521  
522  
523  
524  
525  
526  
527  
528  
529  
530  
531  
532  
533  
534  
535  
536  
537  
538  
539  
540  
541  
542  
543  
544  
545  
546  
547  
548  
549  
550  
551  
552  
553  
554  
555  
556  
557  
558  
559  
560  
561  
562  
563  
564  
565  
566  
567  
568  
569  
570  
571  
572  
573  
574  
575  
576  
577  
578  
579  
580  
581  
582  
583  
584  
585  
586  
587  
588  
589  
590  
591  
592  
593  
594  
595  
596  
597  
598  
599  
600  
601  
602  
603  
604  
605  
606  
607  
608  
609  
610  
611  
612  
613  
614  
615  
616  
617  
618  
619  
620  
621  
622  
623  
624  
625  
626  
627  
628  
629  
630  
631  
632  
633  
634  
635  
636  
637  
638  
639  
640  
641  
642  
643  
644  
645  
646  
647  
648  
649  
650  
651  
652  
653  
654  
655  
656  
657  
658  
659  
660  
661  
662  
663  
664  
665  
666  
667  
668  
669  
670  
671  
672  
673  
674  
675  
676  
677  
678  
679  
680  
681  
682  
683  
684  
685  
686  
687  
688  
689  
690  
691  
692  
693  
694  
695  
696  
697  
698  
699  
700  
701  
702  
703  
704  
705  
706  
707  
708  
709  
710  
711  
712  
713  
714  
715  
716  
717  
718  
719  
720  
721  
722  
723  
724  
725  
726  
727  
728  
729  
730  
731  
732  
733  
734  
735  
736  
737  
738  
739  
740  
741  
742  
743  
744  
745  
746  
747  
748  
749  
750  
751  
752  
753  
754  
755  
756  
757  
758  
759  
760  
761  
762  
763  
764  
765  
766  
767  
768  
769  
770  
771  
772  
773  
774  
775  
776  
777  
778  
779  
780  
781  
782  
783  
784  
785  
786  
787  
788  
789  
790  
791  
792  
793  
794  
795  
796  
797  
798  
799  
800  
801  
802  
803  
804  
805  
806  
807  
808  
809  
810  
811  
812  
813  
814  
815  
816  
817  
818  
819  
820  
821  
822  
823  
824  
825  
826  
827  
828  
829  
830  
831  
832  
833  
834  
835  
836  
837  
838  
839  
840  
841  
842  
843  
844  
845  
846  
847  
848  
849  
850  
851  
852  
853  
854  
855  
856  
857  
858  
859  
860  
861  
862  
863  
864  
865  
866  
867  
868  
869  
870  
871  
872  
873  
874  
875  
876  
877  
878  
879  
880  
881  
882  
883  
884  
885  
886  
887  
888  
889  
890  
891  
892  
893  
894  
895  
896  
897  
898  
899  
900  
901  
902  
903  
904  
905  
906  
907  
908  
909  
910  
911  
912  
913  
914  
915  
916  
917  
918  
919  
920  
921  
922  
923  
924  
925  
926  
927  
928  
929  
930  
931  
932  
933  
934  
935  
936  
937  
938  
939  
940  
941  
942  
943  
944  
945  
946  
947  
948  
949  
950  
951  
952  
953  
954  
955  
956  
957  
958  
959  
960  
961  
962  
963  
964  
965  
966  
967  
968  
969  
970  
971  
972  
973  
974  
975  
976  
977  
978  
979  
980  
981  
982  
983  
984  
985  
986  
987  
988  
989  
990  
991  
992  
993  
994  
995  
996  
997  
998  
999  
1000  
1001  
1002  
1003  
1004  
1005  
1006  
1007  
1008  
1009  
1010  
1011  
1012  
1013  
1014  
1015  
1016  
1017  
1018  
1019  
1020  
1021  
1022  
1023  
1024  
1025  
1026  
1027  
1028  
1029  
1030  
1031  
1032  
1033  
1034  
1035  
1036  
1037  
1038  
1039  
1040  
1041  
1042  
1043  
1044  
1045  
1046  
1047  
1048  
1049  
1050  
1051  
1052  
1053  
1054  
1055  
1056  
1057  
1058  
1059  
1060  
1061  
1062  
1063  
1064  
1065  
1066  
1067  
1068  
1069  
1070  
1071  
1072  
1073  
1074  
1075  
1076  
1077  
1078  
1079  
1080  
1081  
1082  
1083  
1084  
1085  
1086  
1087  
1088  
1089  
1090  
1091  
1092  
1093  
1094  
1095  
1096  
1097  
1098  
1099  
1100  
1101  
1102  
1103  
1104  
1105  
1106  
1107  
1108  
1109  
1110  
1111  
1112  
1113  
1114  
1115  
1116  
1117  
1118  
1119  
1120  
1121  
1122  
1123  
1124  
1125  
1126  
1127  
1128  
1129  
1130  
1131  
1132  
1133  
1134  
1135  
1136  
1137  
1138  
1139  
1140  
1141  
1142  
1143  
1144  
1145  
1146  
1147  
1148  
1149  
1150  
1151  
1152  
1153  
1154  
1155  
1156  
1157  
1158  
1159  
1160  
1161  
1162  
1163  
1164  
1165  
1166  
1167  
1168  
1169  
1170  
1171  
1172  
1173  
1174  
1175  
1176  
1177  
1178  
1179  
1180  
1181  
1182  
1183  
1184  
1185  
1186  
1187  
1188  
1189  
1190  
1191  
1192  
1193  
1194  
1195  
1196  
1197  
1198  
1199  
1200  
1201  
1202  
1203  
1204  
1205  
1206  
1207  
1208  
1209  
1210  
1211  
1212  
1213  
1214  
1215  
1216  
1217  
1218  
1219  
1220  
1221  
1222  
1223  
1224  
1225  
1226  
1227  
1228  
1229  
1230  
1231  
1232  
1233  
1234  
1235  
1236  
1237  
1238  
1239  
1240  
1241  
1242  
1243  
1244  
1245  
1246  
1247  
1248  
1249  
1250  
1251  
1252  
1253  
1254  
1255  
1256  
1257  
1258  
1259  
1260  
1261  
1262  
1263  
1264  
1265  
1266  
1267  
1268  
1269  
1270  
1271  
1272  
1273  
1274  
1275  
1276  
1277  
1278  
1279  
1280  
1281  
1282  
1283  
1284  
1285  
1286  
1287  
1288  
1289  
1290  
1291  
1292  
1293  
1294  
1295  
1296  
1297  
1298  
1299  
1300  
1301  
1302  
1303  
1304  
1305  
1306  
1307  
1308  
1309  
1310  
1311  
1312  
1313  
1314  
1315  
1316  
1317  
1318  
1319  
1320  
1321  
1322  
1323  
1324  
1325  
1326  
1327  
1328  
1329  
1330  
1331  
1332  
1333  
1334  
1335  
1336  
1337  
1338  
1339  
1340  
1341  
1342  
1343  
1344  
1345  
1346  
1347  
1348  
1349  
1350  
1351  
1352  
1353  
1354  
1355  
1356  
1357  
1358  
1359  
1360  
1361  
1362  
1363  
1364  
1365  
1366  
1367  
1368  
1369  
1370  
1371  
1372  
1373  
1374  
1375  
1376  
1377  
1378  
1379  
1380  
1381  
1382  
1383  
1384  
1385  
1386  
1387  
1388  
1389  
1390  
1391  
1392  
1393  
1394  
1395  
1396  
1397  
1398  
1399  
1400  
1401  
1402  
1403  
1404  
1405  
1406  
1407  
1408  
1409  
1410  
1411  
1412  
1413  
1414  
1415  
1416  
1417  
1418  
1419  
1420  
1421  
1422  
1423  
1424  
1425  
1426  
1427  
1428  
1429  
1430  
1431  
1432  
1433  
1434  
1435  
1436  
1437  
1438  
1439  
1440  
1441  
1442  
1443  
1444  
1445  
1446  
1447  
1448  
1449  
1450  
1451  
1452  
1453  
1454  
1455  
1456  
1457  
1458  
1459  
1460  
1461  
1462  
1463  
1464  
1465  
1466  
1467  
1468  
1469  
1470  
1471  
1472  
1473  
1474  
1475  
1476  
1477  
1478  
1479  
1480  
1481  
1482  
1483  
1484  
1485  
1486  
1487  
1488  
1489  
1490  
1491  
1492  
1493  
1494  
1495  
1496  
1497  
1498  
1499  
1500  
1501  
1502  
1503  
1504  
1505  
1506  
1507  
1508  
1509  
1510  
1511  
1512  
1513  
1514  
1515  
1516  
1517  
1518  
1519  
1520  
1521  
1522  
1523  
1524  
1525  
1526  
1527  
1528  
1529  
1530  
1531  
1532  
1533  
1534  
1535  
1536  
1537  
1538  
1539  
1540  
1541  
1542  
1543  
1544  
1545  
1546  
1547  
1548  
1549  
1550  
1551  
1552  
1553  
1554  
1555  
1556  
1557  
1558  
1559  
1560  
1561  
1562  
1563  
1564  
1565  
1566  
1567  
1568  
1569  
1570  
1571  
1572  
1573  
1574  
1575  
1576  
1577  
1578  
1579  
1580  
1581  
1582  
1583  
1584  
1585  
1586  
1587  
1588  
1589  
1590  
1591  
1592  
1593  
1594  
1595  
1596  
1597  
1598  
1599  
1600  
1601  
1602  
1603  
1604  
1605  
1606  
1607  
1608  
1609  
1610  
1611  
1612  
1613  
1614  
1615  
1616  
1617  
1618  
1619  
1620  
1621  
1622  
1623  
1624  
1625  
1626  
1627  
1628  
1629  
1630  
1631  
1632  
1633  
1634  
1635  
1636  
1637  
1638  
1639  
1640  
1641  
1642  
1643  
1644  
1645  
1646  
1647  
1648  
1649  
1650  
1651  
1652  
1653  
1654  
1655  
1656  
1657  
1658  
1659  
1660  
1661  
1662  
1663  
1664  
1665  
1666  
1667  
1668  
1669  
1670  
1671  
1672  
1673  
1674  
1675  
1676  
1677  
1678  
1679  
1680  
1681  
1682  
1683  
1684  
1685  
1686  
1687  
1688  
1689  
1690  
1691  
1692  
1693  
1694  
1695  
1696  
1697  
1698  
1699  
1700  
1701  
1702  
1703  
1704  
1705  
1706  
1707  
1708  
1709  
1710  
1711  
1712  
1713  
1714  
1715  
1716  
1717  
1718  
1719  
1720  
1721  
1722  
1723  
1724  
1725  
1726  
1727  
1728  
1729  
1730  
1731  
1732  
1733  
1734  
1735  
1736  
1737  
1738  
1739  
1740  
1741  
1742  
1743  
1744  
1745  
1746  
1747  
1748  
1749  
1750  
1751  
1752  
1753  
1754  
1755  
1756  
1757  
1758  
1759  
1760  
1761  
1762  
1763  
1764  
1765  
1766  
1767  
1768  
1769  
1770  
1771  
1772  
1773  
1774  
1775  
1776  
1777  
1778  
1779  
1780  
1781  
1782  
1783  
1784  
1785  
1786  
1787  
1788  
1789  
1790  
1791  
1792  
1793  
1794  
1795  
1796  
1797  
1798  
1799  
1800  
1801  
1802  
1803  
1804  
1805  
1806  
1807  
1808  
1809  
1810  
1811  
1812  
1813  
1814  
1815  
1816  
1817  
1818  
1819  
1820  
1821  
1822  
1823  
1824  
1825  
1826  
1827  
1828  
1829  
1830  
1831  
1832  
1833  
1834  
1835  
1836  
1837  
1838  
1839  
1840  
1841  
1842  
1843  
1844  
1845  
1846  
1847  
1848  
1849  
1850  
1851  
1852  
1853  
1854  
1855  
1856  
1857  
1858  
1859  
1860  
1861  
1862  
1863  
1864  
1865  
1866  
1867  
1868  
1869  
1870  
1871  
1872  
1873  
1874  
1875  
1876  
1877  
1878  
1879  
1880  
1881  
1882  
1883  
1884  
1885  
1886  
1887  
1888  
1889  
1890  
1891  
1892  
1893  
1894  
1895  
1896  
1897  
1898  
1899  
1900  
1901  
1902  
1903  
1904  
1905  
1906  
1907  
1908  
1909  
1910  
1911  
1912  
1913  
1914  
1915  
1916  
1917  
1918  
1919  
1920  
1921  
1922  
1923  
1924  
1925  
1926  
1927  
1928  
1929  
1930  
1931  
1932  
1933  
1934  
1935  
1936  
1937  
1938  
1939  
1940  
1941  
1942  
1943  
1944  
1945  
1946  
1947  
1948  
1949  
1950  
1951  
1952  
1953  
1954  
1955  
1956  
1957  
1958  
1959  
1960  
1961  
1962  
1963  
1964  
1965  
1966  
1967  
1968  
1969  
1970  
1971  
1972  
1973  
1974  
1975  
1976  
1977  
1978  
1979  
1980  
1981  
1982  
1983  
1984  
1985  
1986  
1987  
1988  
1989  
1990  
1991  
1992  
1993  
1994  
1995  
1996  
1997  
1998  
1999  
2000  
2001  
2002  
2003  
2004  
2005  
2006  
2007  
2008  
2009  
2010  
2011  
2012  
2013  
2014  
2015  
2016  
2017  
2018  
2019  
2020  
2021  
2022  
2023  
2024  
2025  
2026  
2027  
2028  
2029  
2030  
2031  
2032  
2033  
2034  
2035  
2036  
2037  
2038  
2039  
2040  
2041  
2042  
2043  
2044  
2045  
2046  
2047  
2048  
2049  
2050  
2051  
2052  
2053  
2054  
2055  
2056  
2057  
2058  
2059  
2060  
2061  
2062  
2063  
2064  
2065  
2066  
2067  
2068  
2069  
2070  
2071  
2072  
2073  
2074  
2075  
2076  
2077  
2078  
2079  
2080  
2081  
2082  
2083  
2084  
2085  
2086  
2087  
2088  
2089  
2090  
2091  
2092  
2093  
2094  
2095  
2096  
2097  
2098  
2099  
2100  
2101  
2102  
2103  
2104  
2105  
2106  
2107  
2108  
2109  
2110  
2111  
2112  
2113  
2114  
2115  
2116  
2117  
2118  
2119  
2120  
2121  
2122  
2123  
2124  
2125  
2126  
2127  
2128  
2129  
2130  
2131  
2132  
2133  
2134  
2135  
2136  
2137  
2138  
2139  
2140  
2141  
2142  
2143  
2144  
2145  
2146  
2147  
2148  
2149  
2150  
2151  
2152  
2153  
2154  
2155  
2156  
2157  
2158  
2159  
2160  
2161  
2162  
2163  
2164  
2165  
2166  
2167  
2168  
2169  
2170  
2171  
2172  
2173  
2174  
2175  
2176  
2177  
2178  
2179  
2180  
2181  
2182  
2183  
2184  
2185  
2186  
2187  
2188  
2189  
2190  
2191  
2192  
2193  
2194  
2195  
2196  
2197  
2198  
2199  
2200  
2201  
2202  
2203  
2204  
2205  
2206  
2207  
2208  
2209  
2210  
2211  
2212  
2213  
2214  
2215  
2216  
2217  
2218  
2219  
2220  
2221  
2222  
2223  
2224  
2225  
2226  
2227  
2228  
2229  
2230  
2231  
2232  
2233  
2234  
223